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XIII.

CONCERNING THE LIFE-HISTORY OF *SACCORHIZA DERMATODEA*, (DE LA PYL.) J. AG.

BY WILLIAM ALBERT SETCHELL.

Presented by W. G. Farlow, June 10, 1891.

WE owe our first knowledge of this interesting species to Baron de la Pylaie, who discovered it in 1816, on his first visit to Newfoundland and the neighboring islands of St. Pierre and Miquelon. He deposited specimens of this plant with the Museum of Paris in 1817, and gave to it the name of *Laminaire en forme de cuir*, or *Laminaria dermatodea.* In his second voyage to Newfoundland, in 1819, De la Pylaie extended his observation on this species. In 1824 he published the name given to the herbarium specimens, as well as a few remarks on the affinities of the species, in the " Annales des Sciences Naturelles." But it was not until 1829, however, that he gave any detailed account of its form and structure. In that year he published the first part of the " Flore de Terre Neuve," a work which was to include descriptions of all the plants collected by him in the " New World." This part, however, was the only one ever published, and that lacks the plates intended to accompany it.

The description both of the external form and the internal structure published in the " Flore de Terre Neuve " is very full. De la Pylaie considered that it replaced on the shores of Newfoundland the *Laminaria bulbosa* of Europe, whose near relative he rightly judged it to be. The name was suggested by the thickness and leathery consistency of the adult plant.

The plant thus discovered and described has since been found in several other places, and a number of references have been made to it. A list of as many as have come under the notice of the writer is appended to this paper.

Distribution. — The range of *Saccorhiza dermatodea* seems to be circumpolar. It is found at Vancouver's Island, on the western coast of North America,* and along the shore of Southwestern Kamtschatka.* Kjellman also credits it to the North Pacific.† It is, indeed, unknown either in the American Arctic Sea ‡ or in the Siberian Sea; but the former has never been explored to any extent, and although the latter has been more thoroughly searched, the physical conditions over the greater portion of it are unfavorable to the growth of any algæ. § The species reappears in the Murman Sea,‖ extends into the White Sea, ¶ and thence along the northern coasts of Norway.** In the Greenland Sea it occurs at Spitzbergen,†† and at "Beeren Eiland." ‡‡ It is found in Baffin's Bay on the western coast of Greenland, §§ and extends down along the eastern coast of North America nearly to Cape Cod. ‖‖

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* Harvey, Proc. Linn. Soc., Vol. VI. p. 166, 1862.

From the scanty references to the occurrence of *Saccorhiza dermatodea* in the North Pacific, one might infer that it is very scarce there. The locality in the Arctic Ocean where it is most abundant is, according to Kjellman, the northern coast of Norway; but even there, he says, "it does not occur in any such numbers as are comparable in any way with other *Laminariaceæ*." On page 96 of his "New England Algæ," Farlow has called attention to the fact that this species is of much rarer occurrence on the New England coast than almost any other species of the same family; and that, while rare at its southern limit in the region of Boston, Mass., it becomes more abundant on the coast of Maine. My own experience in collecting on the New England coast fully confirms this. It has never been found growing south of Nahant, Mass., where it is ordinarily rather rare. Farther north at Portland and Mount Desert Island, Maine, it is more plentiful, while at Eastport, Maine, it is said to be fairly abundant.

Habitat. — Eaton ¶¶ records that a specimen was brought up by the dredge through twenty-five fathoms of water off Campobello Island, near Eastport. Kjellman * says that "in the Arctic Sea proper the present species occurs in company with other *Laminariaceæ*, and is usually met with here at a depth of 2–10 fathoms on rocky or stony bottom"; but "on the coast of Norway," he says, "it does not belong to the proper formation of *Laminariaceæ*, but descends deeper than this, even to a depth of twenty fathoms. But it is most common here," he adds, "in shallow, rather exposed bays on gravelly bottom in 4–5 fathoms." Farlow states † that at Eastport it is found in deep pools, but that elsewhere it is an inhabitant of deep water. I have found it at Peak's Island, growing in shallow pools between tide marks, and down to eight or ten feet below low-water mark. I did not search for it at a greater depth. At Marblehead, Mass., it occurred in a very shallow pool at extreme low-water mark. At Nahant, in May and June, 1889, it grew in abundance just below low-water mark, and in pools between tides. But a number of specimens were found in two rather deep pools at the uppermost tide limit.

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* Rupr., Tange Och., pp. 352 and 409, 1847.

† Arct. Alg., p. 38, 1883.

‡ Cf. Kjellman, *loc. cit.*, pp. 4 and 5, for the divisions of the Arctic Sea.

§ Kjellm., *loc. cit.*, p. 26.

‖ Kjellm., Alg. Murm., p. 36, 1877.

¶ *L. Bærii*, Post. & Rupr., Ill. Alg., p. ii, 1840 (*fide* Areschoug).

** Aresch., Obs. Phyc., Part III. p. 11, 1875. Kjellm., Arct. Alg., p. 225.

†† J. Ag., Spets. Alg. Till., p. 31, 1868. Kjellm., Arct. Alg., p. 225.

‡‡ Kjellm., Arct. Alg., p. 225.

§§ J. Ag., Grönl. Lam. och Fuc., p. 11, 1872.

‖‖ De la Pyl., Ann. Sci. Nat., Ser. 1, Tom. IV. p. 179, 1824; Fl. Terre Neuve, p. 48, 1829. Farlow, N. E. Alg., p. 95, 1881.

¶¶ Trans. Conn. Acad., Vol. II. p. 343, 1873.

Season. — De la Pylaie mentions ‡ that numerous very young specimens were cast ashore about the end of October; and Kjellman states § that young individuals were common during the winter on the north coast of Spitzbergen, but that on the "coast of Norway younger and older specimens are of rather the same frequency during the summer months, in July and August." The season on the coast of New England seems to correspond with that of the coast of Norway. I have seen young specimens of *Saccorhiza dermatodea* only in late spring and summer. The first young specimens I found were growing at Nahant, just below low-water mark, June 23, 1888, and were only two or three in number. On April 24, 1889, on a visit to Nahant, I found the pools full of young *Laminarieæ* of small size, among which young specimens of the present species were tolerably abundant. These were of different lengths, and a number of specimens were collected. A careful search was made for the very earliest stages, but none were found. Some very small plants were obtained, but none of the very earliest. It may be present in large numbers in a given locality at one season, and almost entirely wanting during the next. In June, 1888, on the northeastern side of Peak's Island, hundreds of beautiful large plants were growing just a few feet below low-water mark; but in June, 1889, not a single plant was to be found in the same locality, even after a very careful search. In June, 1888, only a very few plants were to be found in the tide-pools at Nahant, and those occurring in the very lowest; but in May and June, 1889, all the tide-pools were full of young plants, even the very uppermost. In the mass of kelps thrown ashore after storms are to be found comparatively few individuals of this species. They are usually more abundantly cast up in February and March than in the other months, and are for the most part old plants, which are often much mutilated.

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* Arct. Alg., p. 225.

† N. E. Alg., p. 96.

‡ Fl. Terre Neuve, p. 49.

§ *Loc. cit.*, p. 225.

Material. — The material on which the present paper is based was collected, for the greater part, by the writer on the shores of Maine and Massachusetts. During the year 1889 the tide-pools at Nahant, Mass., furnished an excellent place for observing this species in almost all of its stages. The first collections were made in the last week of April, and the locality was visited from time to time until June of the following year. Collections were also made at various times at Marblehead, Mass., and at Peak's Island, near Portland, Maine. From these various collections specimens of all ages were preserved in alcohol of about fifty per cent strength, and numerous notes and observations made from them while living. Consequently a number of interesting facts concerning the development have been revealed, and certain relationships more firmly established. In the following paper the morphology of the different periods in the life-history will be given first, and then the histological details of these same periods.

MORPHOLOGY.

Literature. — The first description of the plant is the one by De la Pylaie in the "Flore de Terre Neuve." He describes in full the morphology of the adult plant and that of several stages of development. He emphasizes one point about the origin of the permanent holdfast, which seems to have been entirely overlooked by later writers. Areschoug* was the next writer to add much to our stock of information. He gives a number of very valuable details concerning the size and form of some plants of different ages, and is the first to announce the discovery of this species in Northern Norway and to distribute specimens of it.† On the label of the specimen distributed he remarks, "cum speciminibus e Lapponica Rossica nomine *L. Bærii,* Post. & Rupr. acceptis melius quam cum speciminibus e Terra Nova convenit nostra planta." The first part of the sentence is very valuable, as it establishes the identity of the *L. Bærii* of Postels and Ruprecht. As to the second part, however it may have been with Areschoug's American specimens, the plant distributed agrees so completely with New England specimens that there can be no doubt that the Norwegian and New England forms belong to the same species. Farlow* gives a very careful account of the New England plant, and Kjellman † adds greatly to our knowledge of the Arctic forms of the species.

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* Obs. Phyc., Part. III. p. 11.

† Alg. Scand. Exss., No. 213, under the name of *Laminaria lorea.*

An interesting paper closely connected with this subject, and one to which I am indebted for many valuable suggestions, is one by Mr. P. A. Barber, entitled, "On the Structure and Development of the Bulb in *Laminaria bulbosa*." ‡ This paper has made possible a fairly satisfactory comparison between the earlier stages of *Laminaria bulbosa*, Lamour., and of *L. dermatodea*, De la Pyl., and helped to make the discussion of the relationship existing between the two species much more satisfactory.

Periods. — For convenience of description, the life-history of *Saccorhiza dermatodea* may be divided into four periods, each of which is characterized by some important changes in development.

First Period. — This period naturally deals with the development from the spore. The material is wanting for any satisfactory treatment, and as the plants are at first of microscopic size, these earlier stages will be discussed under the portion devoted to the histology.

Second Period. — 1. *Earliest Stages found.* — The smallest specimens available are two or three which measure 5 to 6 mm. in length. They were found growing in the same clusters with larger ones of the same species, and were detected only by very careful search. Smaller ones were sought for through each bunch collected, but none were found. A hand lens is necessary in examining these specimens. The point of attachment has been lost in every case. The stipe is distinct, and is about 1 mm. long and 0.14 mm. wide at the middle. It seems to be nearly cylindrical in shape, and expands gradually into the blade at the upper portion. The blade, which has thus a wedge-shaped base, is generally ovate or obovate, the broadest portion being in most cases about two thirds of the way from the base. The tip of the blade either tapers to a more or less acute point, or is blunt and truncated from having lost the terminal portion. Below, the stipe appears to be prolonged into the blade one third to one half the way up, as a sort of broad midrib. The midrib-like portion is rather wide at the base, and tapers gradually to a point. The edges are not straight lines, but are somewhat notched or toothed. As seen with the lens, the apex of this portion is not acute, but is somewhat blunt. (Cf. Figs. 1 and 2.)

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* N. E. Alg., p. 95.

† Arct. Alg., p. 223.

‡ Annals of Botany, Vol. III. No. IX. p. 41, February, 1889.

The midrib is very striking in fresh specimens as it is of a deeper color than the rest of the blade. When examined with a low power (150 diameters), it is seen to be thicker and of more complex structure than the rest of the blade, which appears on focusing to be a simple membrane composed of a single layer of cells. The further details of this structure properly come under the sections devoted to the histology.

On some of these young specimens are to be found small clusters of hairs arising from the surface not only of the more complex portion, but also in some cases from the membranaceous outer part of the blade. These are the cryptostomata or " Fasergrübchen." By the presence of these organs the young plants of *Saccorhiza dermatodea* may be distinguished from the young plants of any of the other species of *Laminarieæ* of the New England coast, except from those of species of *Alaria*. From these they may be distinguished, after a little experience, by the outline and the color. *Saccorhiza dermatodea* in these early stages is usually elliptical to obovate, while the species of *Alaria* uniformly have a narrowly linear frond. The color of the young *Saccorhizæ* is light brown. They become somewhat greenish in drying at times, but generally take on a more yellow tint. The young *Alariæ* are of a much lighter brown, and become decidedly greenish on drying. The midrib-like portion in *Alaria*, too, is more linear in shape, and narrower, more like a real midrib. As soon as the *Alariæ* attain any considerable size the true midrib makes its appearance, and distinguishes them at once from the young plants of any of the other species.

2. *Later Stages.* — As the specimens become larger a number of changes may be noticed, which are well shown in a specimen about 3 cm. high. This specimen possesses a distinct organ for attachment, consisting of the slightly dilated basal portion of the stipe and a sort of small cushion by which this is attached to the substratum. The cushion has a spongy appearance and a dirty brown color, and differs decidedly from the stipe both in color and consistency. The stipe itself is about 3 mm. high and about 0.5 mm. in diameter. It is cylindrical in shape, and expands gradually into the lanceolate or

oblanceolate blade, which is about 6 mm. wide. The terminal portion of the blade has disappeared through erosion, but at the tip on either side are seen two narrow strips (cf. Fig. 3, E) of the membrane of the original blade still present. The rest of the blade is more complex in its structure. The cryptostomata are much more numerous and much more conspicuous. They are much larger towards the tip of the blade, and become smaller and smaller as they approach the base, until at the place where the blade passes over into the stipe they disappear altogether. Hence it is reasonable to assume that this transition place, as we may call it, the "Uebergangstelle" of German writers, is a region of active growth.

Third Period. — 1. *Development of the Rhizogen.* — Very soon after the primitive or simple membranaceous blade has thus been very nearly replaced by a blade of more complex structure, and the stipe has elongated to a somewhat greater extent, we come to the beginning of a set of changes in the lower portion of the stipe, which are of great importance in establishing the relationships between this species and others of the same group. The holdfast or organ of attachment in this stage differs from that of the preceding merely in its somewhat greater size. In some of the specimens, however, the holdfast is a vertically elongated body of narrowly conical shape. This variation seems to be the result of peculiar conditions in the substratum to which the plant is attached. The stipe in the specimen chosen as a good illustration of this stage (cf. Fig. 4) is about 8 mm. long and 0.5 mm. in diameter. It is for the greater part of its length cylindrical, but at about 2 mm. from the holdfast it appears somewhat swollen (cf. Fig. 4, B). This swelling, which is regularly ellipsoidal in general outline, is in the specimen chosen about 2 mm. in height and 1 mm. in diameter. Even before this swelling becomes evident, that portion of the stipe where it is to appear seems denser, and is therefore of a slightly different color from the neighboring portions, although at the time it is hard to detect that the surface is at all curved outward. The swelling or node is very readily seen, both in fresh and in alcoholic specimens, and is very nearly as distinct in specimens pressed for preservation in the herbarium.

This swelling is described by De la Pylaie in the "Flore de Terre Neuve" (pp. 49 and 50), and was observed by him in plants thrown ashore about the end of October. His description of a young plant is so excellent that I reproduce it here. "Tout le végétal n'avait alors que 2 à 3 centimètres de hauteur, et sa fronde, d'une délicatesse infinie, n'avait en largeur que 3 millimètres au plus. Cette fronde un peu réservée en pointe à son sommet puis ensuite linéaire sur la plus grande partie de sa longeur, s'amincit successivement jusqu'à se terminer par un petit stipe presque capillaire, où l'on distingue néanmoins, au dessus de son point radical, l'espèce de petit nœud (Rhizogène), que j'ai vu plus tard s'accroître et donner naissance aux principales racines qui fixent cette Algue aux corps solides." It is very evident from this description that De la Pylaie recognized this swelling just above the primitive discoid attachment as well as its function, and that he gave to it the name of "Rhizogène." In regard to this organ and the term applied to it, he explains in a foot-note as follows: "Organe exclusif à cette hydrophyte et au *L. bulbosa;* il n'existe que chez ces espèces dans tout le règne végétal! n'ayant pas encore été désigné par un nom particulier, je propose celui-ci dont je me servirai pour éviter périphrases." This name, Anglicized to rhizogen, will be adopted in this paper to designate this organ. The blade in specimens in this stage varies from 3.5 cm. to 6.5 cm., and is perhaps at times even longer. It is narrowly cuneate at the base, and still bears some traces of the primitive blade at the apex (cf. Fig. 4, E).

2. *Development of the First Hapteres.* — For a number of stages now the changes which take place in the rhizogen are of particular interest. It increases, chiefly in diameter, until it projects out around the stipe in the form of a circular ridge, as shown in Figure 5 at B. This specimen is 7.3 cm. long. The holdfast is a disk-shaped body about 2 mm. in diameter. It will be best hereafter to distinguish this first organ for attachment to the substratum as the *primitive disk* or *primitive holdfast.* The rhizogen is situated about 2 mm. above this, and forms a conspicuous projecting circular ridge, about 3 mm. in diameter. Its upper surface is convex and rounded, while the lower surface is concave to a slight extent. Its projecting edge is coarsely crenate into five small lobes. The stipe in this specimen is 7 mm. long and 1.5 mm. in diameter. The base of the lamina is narrowly cuneate, as in the preceding period, but the blade itself is more lanceolate, occurring very linearly lanceolate in some specimens. A trace of the primitive blade (cf. Fig. 5, E) still lingers in some specimens. The cryptostomata are very abundant in this stage.

As the plants increase in size the rhizogen continues to grow. It increases in diameter proportionally with the stipe. The lobes, scarcely noticeable at the beginning, grow out into finger-like processes (cf. Fig. 6, F), which extend out at first nearly horizontally, and then more and more obliquely downwards. Figure 6 represents a specimen in this stage ; its length is 13 cm. The rhizogen is 5 mm. from the primitive disk, which is slightly larger than in the last specimen described, but not otherwise different. The rhizogen itself is about 4 mm. in diameter. It has several lobes of some length, which are already started downward. The blade presents no particular differences in form, but in specimens of this stage it is very rare indeed to find any trace of the primitive blade remaining.

In somewhat older specimens the finger-like projections have reached the substratum, have flattened their tips against it, and have become attached to it. There are usually five projections, and they form a whorl of attaching organs, which constitute the second holdfast. They are called hapteres by most recent writers,* after the term used by Warming † to designate very similar organs in the *Podostemaceæ.* The hapteres form a regular whorl (cf. Figs. 7 and 9), and their points of attachment form a circle about the point of attachment of the primitive disk (cf. Fig. 8). The development of the hapteres marks the end of the first stage of what is to be the permanent holdfast of the plant, and confirms De la Pylaie's statement quoted above.

3. *Development of the Second Hapteres.* — In the next series of forms, the second and last stage of the permanent holdfast is formed in a manner essentially the same as that in which the first stage was developed. On the rhizogen above the primary whorl a new whorl of protuberances appears. These protuberances are in most cases regularly alternate with the hapteres of the first whorl, but may at times be so placed that one or more of this set are situated above similarly placed hapteres of the first whorl. While the new hapteres are developing, the older hapteres increase in length, and on this account come to occupy a more upright position (cf. Fig. 7 with Fig. 9). The new hapteres, therefore, have the opportunity of growing down obliquely, and of attaching themselves to the substratum, after the manner of those of the first set. Their points of attachment form a second but rather irregular circle outside the one made by the ends of the primary hapteres. We now have three sets of attaching organs: first, the primitive disk; second, the primary whorl of hapteres, all of which are usually present at this stage; and third, the secondary whorl of hapteres. It often happens that some of the hapteres of the second set remain as mere protuberances after the rest of

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* Foslie, Die Lam. Norwegens, pp. 6 and 7, 1884. Barber, Annals of Botany, Vol. III. p. 48.

† Bot. Zeit., Bd. XLI. pp. 193 and 197, 1883.

the members of the whorl have reached the substratum and have become attached. This generally occurs at a place where two of the hapteres of the first set remain close together. In such a case the secondary hapteres may never develop at all, and their place may be permanently supplied by members of the first whorl. But, as a general rule, all the hapteres of this second set reach their full development, and constitute the important part of the permanent holdfast. The smallest specimen examined which shows the protuberances that are to grow out into the secondary hapteres is 16 cm. long, while one that has reached a length of 30.5 cm. has most of the second set attached, but many of them only slightly. In this specimen the primitive disk has entirely disappeared, and there are five hapteres of the first set, which is apparently the original number. Of the second set only two are firmly attached; three are just touching the substratum; and there are two more just showing as small protuberances from the disk of the rhizogen. The stipe of this specimen is 5 cm. long and 3 mm. in diameter at the base. Below, it is cylindrical, but in the upper portion it is noticeably flattened. Even in a specimen of this size the stipe expands gradually into the blade, which in what seems to be the most common form in New England is broader in proportion to the length than in previous stages. This blade is elliptical-lanceolate, 25.5 cm. long and 4.8 cm. wide in the broadest part, which is about half the length from the base. The cryptostomata are very abundant and very conspicuous.

All of the previously mentioned forms were obtained from the pools at Nahant in the gatherings made on April 24 and 25, 1889. The two or three largest and most developed specimens came from below low-water mark, while the younger specimens came for the most part from the uppermost pools. On May 12, some specimens collected from the higher pools were about as large as the largest specimens of the first collection.

On May 25, a few specimens were collected at Peak's Island, Maine, the measurements of some of which are given in the following table: —

No.	Length of Stipe. cm.	Length of Blade. cm.	Width of Blade. cm.
1	3.2	15.9	1.6
2	5.1	26.9	1.4
3	4.45	26.7	1.6
4	10.8	55.9	1.9
5	10.2	35.6	1.9
6	10.2	99.1	3.8

No.	Length of Stipe. cm.	Length of Blade. cm.	Width of Blade cm.
7	11.4	85.1	3.2
8	9.5	85.1	5.1
9	9.5	56.5	3.5
10	15.2	85.1	3.2
11	12.7	76.2	3.3

As can be seen from the above table, which represent specimens taken at random, all the plants of this collection are remarkably long and narrow. The blade of No. 1 was broken off short, as if by some accident. The tips of the rest were eroded in the customary fashion. Nos. 1 to 9 were found growing in a shallow pool just above low-water mark, while 10 and 11 were found cast ashore on a small beach not far away. All of them were of a remarkably light yellow-brown color, and very pellucid for specimens so long as some of them were. About thirty specimens of much the same character were collected at this locality on the same date. All sorts of transitions between this narrow form and the more ordinary form are found. I have seen plants of this narrow form at Nahant and Marblehead also, but they were few or single, and this is the only time that I ever found so many together.

Fourth Period. — 1. *Transitional Forms.* — Some specimens were collected at Nahant, June 12, 1889, which show some very striking peculiarities. The specimens, between twenty and thirty of which were carefully examined at the time, were all about the same size, and apparently of about the same age. They grew not only just below low-water mark, but in the highest pools as well. They were all in the neighborhood of 55 cm. long. The holdfast was well developed, and the hapteres were stout and of a dark brown color. The stipe was decidedly flattened above, and from 6 to 10 cm. long. At the top where it passes over into the blade there is a noticeable ridge made by the abrupt transition from the thick stipe to the much thinner blade. The stipe has become a very dark brown, and is opaque, having lost entirely the translucent appearance characteristic of the organs of the younger plant. But the most noticeable and interesting change is one which is to be seen in the blade itself. In the upper part of this the color is still decidedly yellowish, and the cryptostomata are abundant and conspicuous; but toward the base there is a noticeable transverse constriction (cf. Fig. 11, A), and below this the blade is of a dark brown, agreeing more nearly with the stipe in color, and almost if not entirely destitute of cryptostomata. The cryptostomata grow smaller and smaller as they approach the constriction and disappear at a small distance above it. Below the constriction not a cryptostoma is to be seen. The outline in the figure just referred to above was traced from the plant itself while fresh, and is to be compared with Figure 10, in which the permanent oar-shaped base of the adult plant is represented.

As the blade grows older and the part below the constriction increases in size, the constriction gradually disappears. In a specimen of this same collection, 73 cm. long, the last traces of the constriction are to be seen at about 10 cm. above the base of the blade. The base of the blade now becomes more blunt, and begins to take on the shape of the base of the blade of an oar, which is very characteristic of the adult plant. The distinction between stipe and blade becomes for the first time sharply marked.

This process resembles in almost all respects the process of renewing the blade so well known now in the European species of *Laminaria*,* and seen by the writer in most of the species of *Laminaria* and *Agarum* of New England. But in this process the old blade, which is thick and is fruiting or has fruited, is cast off, and is succeeded by a new blade of more delicate consistency. In *Saccorhiza dermatodea*, on the contrary, as shown more fully below, the new blade is thicker and denser, and destined to bear the reproductive organs.

It is about this time in its life-history, also, that the plant grows most actively and reaches its maximum of size. The largest specimens I have ever found were growing at Peak's Island, June 28, 1888. The largest specimen of my collection of that date measures 142 cm. when dried. The stipe is 16.5 cm. long, and the blade reaches a width of 12 cm. Hundreds of plants of this size, and even larger, were growing in that locality at that time.

Farlow says in his New England Algæ,† that the stipe sometimes reaches a length of two feet, and the blade a length of six feet. The figures are probably taken from Eastport specimens, where the species is said to grow more luxuriantly than it does farther south. A specimen in the herbarium of Mr. F. S. Collins of Malden, Mass., collected at Eastport in August, was in this same stage of growth. The stipe measured 66 cm. The blade was short and fragmentary, but measured 21.4 cm. in width.

In these large specimens the blade is very thin and papery on drying. The color is still a rather yellowish brown, and the cryptostomata on the upper part are more numerous and more conspicuous than at any other stage. They are larger in these fronds than at any time previous, as will be noted below. In the basal third or half of the blade, however, the cryptostomata are entirely wanting. The color of this portion is darker, and it is thicker and more leathery.

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* Cf. Le Jolis, Examen I., p. 549, 1856; Foslie, Die Lam. Norwegens, p. 23; and earlier writers.

† Page 95.

The stipe is more flattened at the top, and the holdfast is larger and firmer. Occasionally one is found in which one or more of the hapteres is branched. The branching, however, is only a simple forking of the haptere, and may perhaps be regarded as indicating two hapteres, fused together above but free below. This branching, as far as my experience goes, is decidedly rare.

At about this period, and in some cases also somewhat earlier, the blade splits vertically into two or more divisions. Two segments seems to be the rule in the narrower blades, but in the wider ones there are generally three. I have seen a number of specimens where there were four, and in the herbarium of Mr. Collins I have examined one in which there were five. The splits are continued almost to the very base of the frond, and the segments are more or less strap-shaped. The old fronds split very readily in this vertical direction, and one often finds them cast ashore in the springtime split down to the holdfast itself. In Mr. Collins's herbarium there is a specimen which had been split down thus far when young, and each half had proceeded to continue growing, and there are two more or less perfect plants in that case from the same holdfast. It reminds one of the famous bifurcate specimens of *Laminaria digitata*, of which a summary is given by Le Jolis.*

2. *Adult.* — As the season progresses, the plant ceases to grow so actively as at first, and the tip wears away faster than it is renewed. Consequently, the plant becomes shorter as the summer advances, but it also grows thicker and denser. I have unfortunately no specimens collected early in July, but through the kindness of Dr. G. H. Parker of Harvard University I have some excellent specimens collected late in July. These are shorter than the earlier specimens, are of a dark brown color, and very leathery. They show no traces of cryptostomata. In September I collected very similar specimens at Nahant with zoosporangia just forming. In October, specimens with well formed zoosporangia were not uncommon at the same place. Fruiting specimens of this species may be found from October on until May of the next year.

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* Examen I., p. 540.

Kjellmann says[*] that the proper season for the formation of zoospores in this species is in September or the beginning of October, on the Norwegian coast. At Spitzbergen he found specimens with zoosporangia in July and August, and at Nova Zembla in July. There is apparently in the more northern regions an earlier ripening of these bodies.

The fruit occupies about the lower half of the blade in the well developed specimens. The collection of sori, or cloud-like patches of fruit, covers the surface on both sides at the very base of the frond, but separates above into irregular-shaped blotches of considerable size. When the water has evaporated from the surface of the frond, these sori have a peculiarly soft and velvety appearance, and are of a somewhat lighter brown color than when wet. When dried, the mature plants are of a decidedly black color, but the sori are even blacker than the frond, and may thus be detected readily even in herbarium specimens.

De la Pylaie[†] describes the fruit as entirely covering both surfaces of the frond, and as occurring toward the end of autumn. Areschoug[‡] says: "Fructificatio . . . non format maculas extensas l. fascias, ut in Laminariis, sed maculas minutissimas fere punctiformes, nunc separatas, nunc approximatas, quo fit, ut cum siccata est, lamina farina nigrescente conspurcata videatur." The specimens from the New England coast do not agree with this description, as may be seen from what has been said above.[§]

Specimens are cast ashore in the greatest numbers from November until May. I have generally found them most abundant in February. A specimen thrown ashore at Lynn, Mass., February 9, 1890, was in very perfect condition, and so will serve as a good illustration of these very old plants. The lower part of this specimen is represented of the natural size in Figure 10. It measured 70.5 cm. in length, and the holdfast was about 2 cm. in diameter. The primitive disk was still present, although much shrivelled and wrinkled. Of the first set of hapteres three were present in a good state of preservation on one side, and the places where the other two had been were to be seen on the other. There were nine hapteres present in the outside set. All the hapteres were unbranched. The stipe was 12.1 cm. long. It was cylindrical at the base and flattened at the top. The blade had the oar-shaped base characteristic of these old specimens, and expanded gradually until it reached the truncated apex. It was 58.4 cm. long, and 12.7 cm. wide at the top.

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[*] Arct. Alg., p. 225.

[†] Fl. Terre Neuve, p. 49.

[‡] Obs. Phyc., Part. III. p. 12.

[§] Cf. also Kjellman, Spetsb. Thall., II., p. 14, 1877.

A curious thing to be observed in the specimens cast ashore is that the great majority of them lack the holdfast, although the attachment by this organ does not seem to be a very firm one; for if one catches hold of a growing plant, even by the tip of the blade, and gives it a strong and sudden pull, it almost always comes away from the substratum uninjured, offering in this respect a strong contrast to the ordinary species of the *Laminarieæ.* But the majority of the old specimens cast ashore in the spring look as if they had been twisted off at the lower end of the stipe, and occasionally a bunch of fronds will be found cast up, all twisted together in a most complicated manner.

This species appears to be an annual. De la Pylaie* and Areschoug† were also of this opinion, and all the data that are at hand seem to support it. On the coast of Massachusetts I have never seen an adult plant after May (when old, decaying, fructified specimens were cast ashore) until September. The plants growing in the pools become very battered and torn, and covered with parasites in December and January; and the adult plants found in the springtime are always very old and about to decay. There is, besides, no indication in the structure that the plant is either biennial or perennial.

Summary. — From what has been said above, it will appear that each of the four periods into which the life-history has been divided for convenience has its characteristic features.

The lack of suitable material, and the small size of the germinating plants, prevent any satisfactory discussion here of the changes taking place in the first period and the early portion of the second. Toward the end of the second period, however, the young plant is provided with a distinct disk for attachment, a short cylindrical stipe, and a blade which for the most part is more than one layer of cells thick.

The third period has for its characteristic feature the development of the permanent holdfast. A small swelling, the rhizogen, appears a short distance above the primitive disk, increases in size, and produces two whorls of short fibres, the hapteres, one above the other. The hapteres attach themselves to the substratum by their tips.

The fourth period extends to the death of the plant. In all the preceding stages the base of the frond has been narrowly cuneate, and it has been difficult to determine either where the stipe ended or where the blade began; but at the beginning of this period occurs the process compared above to the process of the renewing of the blade in other *Laminarieæ*, after which the boundary between stipe and blade is well marked, and the blade itself becomes thicker and firmer, and ceases to possess cryptostomata. When this set of changes has fairly ended, the zoosporangia are produced, and the plant, having served its purposes, dies, and gives place to a new generation.

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* Fl. Terre Neuve, p. 49.

† Obs. Phyc., Part. III. p. 12.

HISTOLOGY.

Having thus considered with some detail the various morphological changes which *Saccorhiza dermatodea* undergoes in the course of its life-history, we are in a position to turn to the histological changes which take place during the same period.

Literature. — The histology of this species has been seldom referred to. De la Pylaie's account * does not express to us any very definite idea. Areschoug † has described the structure of the cryptostomata and of the organs of fructification. Kjellmann ‡ has spoken of the structure of the stipe, and especially mentioned the "very long tubular cells, with very thick walls," found in this organ in this species, and lacking in the *Phyllaria lorea* found by him at Spitzbergen and Nova Zembla. Barber, as mentioned above, has described the histological changes occurring in connection with the development of the bulb in *Saccorhiza bulbosa*, De la Pyl., and has thus furnished a valuable means for comparing these two species.

The account of the histology will be arranged according to the periods of development sketched out above.

First Period. — The first period begins with the zoospore and its germination to form a filament of a single row of cells, and extends to the formation of a membrane of a single layer of cells in thickness. No plants of *Saccorhiza dermatodea* belonging to this period have been seen, but evidences of the existence of these early stages are present in the youngest plants known.

As far as I know, Thuret § is the only one who has described or figured either the zoospores or germinating plants of any species of the *Laminarieæ*. He figures the entire development of *Saccorhiza bulbosa* ‖ for this period, as well as the early stages of *Laminaria*

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* Fl. Terre Neuve, pp. 50 to 52.

† Obs. Phyc., Part. III. p. 12.

‡ Arct. Alg., pp. 224 and 225.

§ Ann. Sci. Nat., Ser. 3, Tom. XIV. Pl. 29 and 30, 1850.

‖ *Loc. cit.*, Pl. 30, Figs. 5 to 10.

saccharina.[*] Kützing[†] figures and describes young plants of *Laminaria saccharina* consisting of a simple membrane. I have seen a young plant, probably belonging to *Laminaria Phyllitis*, (Stackh.) J. Ag., which consisted of a simple filament.

It seems fairly certain, then, that the germinating zoospore of the *Laminarieæ* gives rise first to a simple filament, and later to a simple membrane; and it seems very probable also that the earliest stages of *Saccorhiza dermatodea* will be found to correspond very closely to those known for *Saccorhiza bulbosa.*

Second Period. — The preceding period is doubtless very short, and changes soon begin which convert the simple membrane into a membranaceous frond of more complex structure. The changes take place in the early portion of what has been marked off as the second period of the development. The youngest specimens in my possession show these changes already well advanced, and have been partially described above in the account of the morphology. They are of very delicate consistency, and are therefore difficult to manipulate. Furthermore, there were only two or three of the very small ones, and on these accounts many of the details of the histology here given had to be derived from somewhat older plants, belonging however to the same period.

When one of the youngest plants is examined under a low power (150 diameters), it is seen that the stipe and the midrib-like portion of the blade have already arrived at some degree of complexity of structure. The outline of this midrib portion, as mentioned above, is irregular (cf. Figs. 1 and 2). In Figure 1 it is seen to have several tooth-like projections from the main portion. One of these (labelled A) is situated at the tip. Somewhat below, at A′, there is another one, and at A″ still another. These are only more prominent than the others at A‴, and so on, but do not differ in kind. At the very tip the blade is eroded, and consequently we find here, as has been described for other *Laminarieæ*, that the growth is not apical, but from below, and that the apex of the blade is the oldest portion. As a still further evidence of this, it can be seen that the apical portion of the blade is of simpler structure, and becomes more complex downward. This is exactly what we should expect from what we know from other members of the group. Consequently, a set of transverse sections of one of the plants, arranged in a series from above downwards, will throw a considerable light on the changes of structure which it has undergone in its previous development. In such a series, projecting portions, such as A′, etc., are of significance in showing that the growth in complexity from the simple membrane did not originate from one point and extend out regularly, but originated at several points irregularly situated. A comparison between Figures 1 and 2 will also show this.

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[*] Ann. Sci. Nat., Ser. 3, Tom. XIV. Pl. 30, Figs. 1-4.

[†] Phyc. Gen., p. 345, Taf. 24, I, Fig. 5, 1843.

To get these sections some series were made by hand with the razor, and more complete ones were cut on a microtome from specimens which had been embedded in paraffine. Some of the latter were from specimens which had been treated with corrosive sublimate. They were stained with Kleinenberg's hæmatoxylin before being embedded, and mounted in balsam after they were cut. Some of the series gave very good results, others were very much shrivelled.

The upper portion of the blade, or the primitive blade as it is convenient to term it, is but a single layer of cells thick, as appears in sections as well as by focusing. As seen on the flat surface of the blade the cells are nearly square or slightly rectangular, but in some cases elongated in the direction of the long axis of the blade. In transverse section they appear nearly as thick as broad, but they vary much in this respect. The cells contain a number of large and conspicuous lenticular chromatophores, usually arranged about the inner walls. The protoplasm in these cells is in the form of a thin film lining the wall. The nucleus is not very conspicuous, and is hard to demonstrate. These cells possess all the characteristics of age, and have probably ceased to take any active part in the growth of the plant.

On the one-layered portion were found in some of the specimens the small clusters of hairs already alluded to. Attempts to get a good section through such a bunch were fruitless. As far as could be seen by focusing, the hairs protruded only on one surface, and were generally five or six in number. When viewed from the other side from that on which they were situated, they were seen to arise from basal cells formed from the divisions from one (or at times from two) of the ordinary cells of this portion of the blade. The basal cells of the hairs are almost isodiametric, are densely filled with protoplasm and chromatophores, and possess a single large nucleus. Farther up, the cells become elongated in the direction of the long axis of the filament; the protoplasm becomes filled with large vacuoles; and the nucleus becomes central, and connected with the peripheral protoplasm by fine threads. At the distal end the cells are four to six times as long as broad, and are destitute of contents. These hairs accordingly have the region of active growth at the base, as do most of the hairs in the *Phæosporeæ*.

In the series of sections the first evidence of an increase in complexity is shown in Figure 12. In this transverse section it will be seen that two cells, at A and A, have divided by walls parallel to the surface of the frond, and that these two cells are not situated side by side, but are separated by one cell. Sections from other plants represent the initial cells somewhat differently. In one case there was a single one, and in another two were side by side. A section from the same series as the one represented in Figure 12, and about 30 μ below it, is represented in Figure 13. In this the process has gone further, and the central portion of the blade is two-layered, while the edges are only one-layered. A longitudinal section of a young blade showed that in that particular specimen the two-layered portion was five cells in height. Soon we come to a section such as that represented in Figure 14, where there is a third cell of different shape and appearance in the centre, and the two layers are separated from each other in the middle to make room for it. This cell lacks the chromatophores, is round in cross-section, and has a lining of dense protoplasm, in which are embedded numerous small nuclei, which take on a deep stain with hæmatoxylin.

In the same figure will be noticed two groups of hairs, one projecting from each surface. Each group seems to have arisen in this case from the divisions of a single cell. In the several-layered blade they are frequently opposite in this fashion.

Figure 15 is drawn much less magnified, and the cells are all represented on one side to show the proportions existing between the many-layered and the one-layered portions of the blade. It will be seen here that there are three of the central cells in this section. In longitudinal section these central cells appear as elongated tubes, the ends of which are not readily found. They will be spoken of as tubes, or tubular cells, for the present.

Figure 16 shows a section still lower in the original series. The many-layered portion is wider, and the cells appear irregularly placed; but the arrangement is seen better in Figures 17 and 18, still lower down. The tubular cells are readily seen at *a* and A. The many-layered blade, about half of which is represented in the figures, has increased chiefly in width. At B in Figure 17 is seen a group of four cells, situated apart in the one-layered portion, which recalls the state of things represented in Figure 12, and looks as if the cells were the initial cells of a new many-layered portion. Such is the case in fact.

This is the origin of the tip of such a portion as that labelled A″ in Figure 1. At B in Figure 18, about 30 μ below the section figured in the preceding, this group of four cells has increased by dividing to form six. The divisions are repeated, and this portion grows wider until the intervening space is traversed and it unites with the main part.

This fact is significant in indicating that there is no one cell, nor even one region, whence all growth proceeds, but several cells and regions, and these somewhat irregularly placed.

As we go down, the outer cells, one by one and at first somewhat irregularly, divide into two by a wall parallel with the surface of the frond, until at length we have a layer of smaller cells on each side, a layer of large cells adjoining each of these, and the tubes in the middle. The outside layers on each side may be called the limiting layers (L in Figs. 19 and 20); the next layers, of larger and more irregular cells on each side, may be spoken of as the cortical layers (C in Figs. 19 and 20); and the tubes alone represent what later demands attention as the medulla.

The lower portion of the blade does not increase in complexity for some distance, but widens until the whole width of the blade is occupied by the many-layered portion. But in the region where the blade narrows and passes gradually over into the stipe, in what has been spoken of above as the transition place, a new set of structures arises, which are intimately concerned with the thickening of the blade and stipe, and the increase in the complexity of the tissues. The fact that this set of changes originates in this portion shows that the principal meristematic region is situated here in this species, as it is in others of the same group.

At the transition place in such specimens the limiting layer is distinct, and consists of rather small cells of nearly equal dimensions in the three principal directions. The cortex has two, or even three, layers of two more or less distinct kinds of cells. Those of the outer layer are like the cells of the simple cortical layer. The inner cells appear in transverse section much like those of the outer layer, except that they are more rounded and lie more separated both from one another and from the outer layer, and in the middle layer among the tubes. In longitudinal sections, however, they are seen to be much more elongated than the outer, some of them being five to six times as long as broad. From them, too, are given off short hyphal branches, which extend out laterally from the cells, and protrude into the middle portion. It was impossible to see the mode of origin of these hyphal branches in the one or two specimens of this period which showed them, and so a more complete account of them is left until the next period is discussed.

The stipe, towards the end of this period, becomes a rather solid structure, composed of the following tissues. Outside is a limiting layer similar to that described for the blade, but which is in a state of more active growth. The cells composing it are somewhat elongated radially, and divide actively by tangential walls. By divisions in the two directions perpendicular to this, it also keeps pace with the growth of the stipe in circumference and length. Within this are several layers of cortical cells, and the centre is occupied by a mass of elongated tubes. No hyphal cells are present except at the transition place.

All except one of the younger specimens had lost the point of attachment. This individual is 6 mm. high. The base is decidedly bulbous, and is 18 mm. wide, while the stipe above is about 0.1 mm. wide. The bulbous base is about 0.13 mm. high. At the bottom it is attached by a number of hair-like bodies, which it seems proper to term rhizoids. These are comparatively numerous (probably between 50 and 60), and arise as prolongations from the cells of the limiting layer of the basal portion of the enlargement. The rhizoids themselves are irregularly cylindrical, and at this stage seem to be for the most part unicellular. Toward the distal end the shape is more irregular, the wall thicker and wrinkled, and at this portion too they are not infrequently and somewhat irregularly branched. The branches are very short and the tips of the rhizoids are somwhat swollen. This specimen was growing among a mass of other young plants and fine filamentous forms of other species, and this allowed the rhizoids to be seen to greater advantage.

The above description is to a certain extent fragmentary, but much of that is due to the character of the available material. That previous to this period there exist stages in which the frond consists of a simple membrane of a single layer of cells seems to be evidenced by the fact that, in the youngest specimen seen, the blade is for the greater part in that condition. It is supported, too, by what we know of the early stages of some nearly related species. What the stages are by which the development proceeds from this simple frond to such a stage as that represented by the youngest specimen described is largely a matter of conjecture. That the complexity comes about by a series of definite and gradual changes seems probable. It is supported, moreover, by what is described above. For in the blade we find at the top, which is the oldest portion, the simplest structure of a single layer of cells. It then becomes two-layered, three-layered, four-layered, five-layered, and finally still more complex by the growth of the hyphal branches.

That the stipe develops somewhat differently is evidenced, not only by its different structure, but also by its different shape. In the absence of a series of earlier stages to indicate the way in which the complexity came about, we have almost nothing to help us; for in a specimen only 6 mm. long the stipe is 12 or 13 cells in diameter. We get a slight clue, however, from a young specimen of *Laminaria Phyllitis* collected at Nahant. In this the stipe consists of a central vertical row of cells and a cylinder of cells about it only one layer thick, so that a transverse section is only three cells across. This seems to indicate that changes to produce the stipe have followed something of the same course that has been followed in the blade, but have been modified in such a way as to produce a cylindrical rather than a flattened structure.

Kützing* figures some details of the development of *Laminaria saccharina* during this second period. Reinke† also mentions the partially one-layered stage of the same species, and gives a rough sketch of it.

Third Period. — The most important feature of the third period, as marked out above, is the development of the rhizogen and the two whorls of hapteres. At the same time, the blade and stipe increase greatly both in size and complexity. The early stages are almost exactly like the later stages of the previous period, except for the development of the swelling which marks the appearance of the rhizogen. It will be best, therefore, to describe first the changes in structure which accompany this.

A longitudinal section through a very young rhizogen shows that the central portion consists wholly of elongated cells arranged in vertical rows. There are no long tubular cells present in this portion. The changes which result in the swelling begin at the centre and proceed outwards. The very central cells increase greatly in diameter, and are followed in this by the outer rows. They tend also to increase in length, but, being hemmed in on all sides, soon have the appearance of being cramped. This process, thus taking place in a certain definite region of the stipe, causes the sides to bulge outwards, and the swelling called the rhizogen results. It is produced by the great increase in the size of the cells, not by any large increase in the number of cells, as Barber[*] has already described for the same organ in *Saccorhiza bulbosa.*

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* Phyc. Gen., p. 345, Taf 24, I, Figs. 1 to 6.

† Pringsh. Jahrb., Bd. X. p. 375, Taf. XXVII. Fig. 18, 1876.

Not only do the inner cells of the rhizogen enlarge, but the walls thicken and separate from one another, except at certain points on each face, where they still remain united. The space between the separated walls is filled for some time with a mucilaginous modification of the outer layers of the cell wall (cellulose); but after a while it is impossible to detect anything of this kind, and the substance probably becomes very watery indeed. However that may be, the spaces between the walls finally become filled with small cells in lines and rows, the origin of which is not readily determined. They appear to bud out from the larger cells in the form of small hyphæ, which, however, become so crowded that they seem to form a compact tissue almost at once, and to lose all trace of their hyphal structure. (Cf. Fig. 21, *b.*)

The limiting layer has continued growing, and at certain places along the equator of the rhizogen, in company with the underlying cortical cells, it takes on a much greater activity than it does elsewhere. The increase at these portions is in the radial direction, and is brought about both by the tangential division of the cells of the limiting layer and by the increase of the cortical cells in the radial diameter. As a result several protuberances are formed in the zone of the equator destined to push out into hapteres. The cortical cells increase to from six to eight times their original radial diameter, and, new cortical cells being supplied by the activity of the limiting layer at the distal end of each protuberance, the haptere begins to elongate. The limiting layer is more active at the summit of a haptere than along its sides; in fact, very few new cells are formed in the latter region at first. Later, however, when it has finished its growth in length, these conditions are reversed, and its growth is then in thickness. When the haptere has reached the substratum in its outward and downward growth, the cells of the limiting layer along the surface in contact with the substratum grow out into rhizoids for attachment like those mentioned in the case of the primitive disk.

The second set of hapteres arises after the first set is fully formed. They develop in exactly the fashion that the members of the first set did.

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[*] Annals of Botany, Vol. III p. 55.

This brief sketch shows how the rhizogen with its two sets of hapteres develops. They do not increase in complexity to any extent during this period. But while this has been taking place there have been important changes in the other organs of the plant.

If we start at the tip of the blade of a specimen which has the first set of hapteres well developed, we shall find it to possess a well defined limiting layer on each surface, and within this, on both sides, a cortical layer of a single series of cells, and in the centre the medulla, represented by a few scattered tubes. As we approach the base, we find the limiting layers more and more sharply defined. Their cells are smaller and more elongated radially, and give evidence of greater activity. Within these the cortical layers are more developed, and are to be distinguished into an inner and an outer layer. The outer layer consists of smaller parenchymatous cells, while the inner contains larger elongated cells. We have, too, at this point a distinct medulla, in which the long tubular cells form a conspicuous element. Surrounding them are elongated tube-like cells of an appearance intermediate between that of the original tubes and the elongated inner cells of the inner cortex. Their walls are thin, while the walls of the original tubes are now noticeably thickened, and they are in general destitute of the dense contents of the latter. They have attached to them and entwining about them numbers of hyphal filaments, which usually have a lateral or oblique direction of growth.

If one examines the innermost rows of cells of the inner cortex in transverse, or better in longitudinal section, he will see whence these hyphæ arise. As the cells of the inner cortex elongate, the middle layer of the common wall becomes swollen, and the cells become finally separated from one another, except at a few points on each face. As the layer continues to swell and to become indistinct, the connections at these points become drawn out into short tubes; and since the process continues, these may become quite long at times. The tubes or hyphæ may be known as connecting hyphæ (Verbindungshyphen). In the other *Laminarieæ*, as far as investigated, they are said to arise only at points on the walls where there are pits, and this seems to be true of the specimens examined; at any rate, in all places where the point of origin could be plainly seen, this was the case. In the region where the cells begin to separate, the cell walls proper are thin, and the pits are not conspicuous. But if the section be stained with a dilute solution of Boehmer's hæmatoxylin the appearances shown in Figure 23 are brought out. In this figure it is seen that at the place where the two cell walls remain in contact there is a thickening which takes on a deeper stain than the comparatively thin walls do. In Figure 23, also, one of these thickenings shown in surface view is seen to be in the form of a ring. In cells which have separated more, and have a connecting hypha, there appears to be just such a thickening at the point in the hypha which represents the place of contact in the originally adjacent cells.

On the longitudinal walls of these inner cells of the inner cortex may also be seen small rounded protuberances which grow out into hyphæ. These hyphæ, which in contrast to the connecting hyphæ may be called free hyphæ, grow horizontally inwards, and twine among the separated elements of the medulla. They sometimes arise from pits, and probably always do, although this was not to be plainly seen in all cases. The hyphæ when just starting do not seem to have a thickened ring at the base, but nearly all of the longer ones do. There seems to be no fundamental distinction between free hyphæ and connecting hyphæ. A connecting hypha may be separated from one of the two cells, either at the middle or at one end, and, thus becoming a free hypha, continue its growth. Where, too, the free hyphæ originate as small protuberances, it is probable that at these points had been situated pits, but that the two cells had nevertheless entirely separated from each other.

The reason why the cells of the medulla and inner cortex become separated from one another is not at all apparent. It is suggested that these cortical cells, growing rapidly in length, become longer than the corresponding region of more external cells, and so, becoming somewhat bent, have a tendency to separate except at places where they are most firmly attached, viz. at the pits. This would seem to go a step farther in the medulla than it does in the inner cortex. In the former the cells separate almost entirely from one another, except as they are united together by the connecting hyphæ, and, the ends being free to slide up or down, the elements can elongate to a much greater extent than they could when they were members of definite vertical rows.

We find, then, at the end of this period, four sorts of cells in a medulla of this stage, viz.: first, the original tubes; second, the tubes arising from the elongation of the cells separated off from the inner cortex; third, the connecting hyphæ; and fourth, the free hyphæ. The further changes in the medulla introduce no new kind of elements, but are brought about by the addition of new elements of the last three kinds, and the changes which these undergo.

The development of the cryptostomata may be readily investigated in the thicker blades at this stage of growth. A series of sections at and a little above the transition place will give all of the early stages. The first indication that a cryptostoma is forming is the appearance of a shallow saucer-shaped depression. This will be seen to be due to the fact that the cells of the limiting layer in the region of this depression cease to divide as actively in a tangential direction as they have been doing, or as actively as their neighbors are doing. Furthermore, the cells of the outer cortex immediately below this point do not increase in size either so rapidly or to so great an extent as their neighbors do. So very soon this region is left behind by the more active growth of the rest of the blade, and forms a slight depression.

Very soon also the cells of the limiting layer at the bottom of this depression begin to grow out into filaments, and a stage of this is represented in Figure 22. In this drawing the filaments or hairs are only three or four cells in length, and still possess the original rounded terminal cell. The growth is at the base, as may be seen from the figure, and as was described in the cases of the clusters of hairs found on the primitive blade. The oldest cryptostomata of specimens of this stage are decidedly bowl-shaped, but they lack entirely the prominent overhanging margin to be found in older specimens.

Fourth Period. — Transitional Forms. — Having developed the permanent holdfast, the plant enters the final period of changes. Early in this, its active vegetative life ends, and it begins to mature and to ripen. At the very beginning, it starts to throw off the old blade, which has been, by means of its thinness and abundant cryptostomata, so well adapted for obtaining nourishment and for assimilating it, and proceeds to develop a frond especially adapted for bearing the reproductive bodies.

Through an oversight, specimens of the stage showing the renewal of the blade were not preserved otherwise than as pressed for the herbarium, and so I am unable to give an account of the stage where the transition takes place. But the change is brought about by a thickening of the walls and a modification of the contents of the cells, rather than by any change in the kinds of elements or in their distribution.

As mentioned above, the growth of the blade is very rapid at about this time, and at the boundary of these two periods the plant attains its maximum length. The most striking thing, perhaps, about one of these large plants, such as were collected at Peak's Island and at Nahant in the latter part of June, is the abundance and size of the cryptostomata. It is in these plants that they reach their final complexity, for in the new blade just forming they are entirely absent. They are saucer- or shallow bowl-shaped depressions, about 0.3 mm. in diameter, 0.15 mm. deep, with a large number (60 to 70) of hairs projecting from the bottom. The margin of the saucer has a sort of rim projecting in over the edge of the depression, such as Areschoug* describes for the Norwegian plant.

Adult Forms. — Specimens collected by Dr. Parker at Nahant, on July 26, 1889, are shorter than the last, have no cryptostomata, are of a darker color, and more leathery in consistency. Sections through the various organs of some of these specimens show the arrangement of tissues much as described in the last; but show also that the walls of all the elements of these tissues have undergone extensive thickenings, and that the elements themselves are somewhat larger. It will be well to glance, then, at the changes which have thus taken place in the tissues of a plant more matured, but not yet fruited. Such plants are common at Nahant in the middle and latter part of September.

a. Limiting Layer. — In these plants the limiting layer is still present, but is covered with a thick secretion resembling a cuticula. The latter may be separated readily from the section, and then has a pitted appearance where it has been parted from the rounded ends of the cells. The cells of the limiting layer, both in stipe and in blade, are usually somewhat elongated radially (cf. Fig. 24, L). The very outside walls and the cuticula give a yellow reaction with chloriodide of zinc solution, but the inner walls turn a pale bluish. At the base of most of the cells small cells may be seen in cross-section (cf. Fig. 24, *a*) which have recently been formed by tangential division. The cells of the limiting layer always have dense contents and numerous brown chromatophores, so that the section needs to be particularly thin to show the cell structure without the use of clearing reagents.

b. Cortical Layers. — The next layers differ in stipe and in blade in the details. In the blade the cortical layer is not at all distinctly divided into inner and outer, as seen in cross-section. In a longitudinal section, however, the innermost cells are elongated and have hyphal outgrowths, while the outer ones are shorter and more irregularly placed. In the stipe the outer cortex appears distinct in a transverse section, from its cells being somewhat elongated radially and arranged in radial rows, although it is not as plain in this species as it is in those of the genus *Laminaria.* The cells of the inner cortex of the stipe appear more nearly hexagonal in transverse section, and are not arranged in radial rows. In a longitudinal section of the stipe the cells of the outer cortex are short and more or less irregularly placed, while the cells of the inner cortex are much elongated and in vertical rows. In the blade there are only a couple of layers of cells in each cortex, but in the stipe there are several layers of cells in each, and the cells of the layers are well supplied with pits.

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* Obs. Phyc., Part. III. p. 12.

The pits among the *Laminariaceæ* are very conspicuous structures, and deserve especial study. They are mentioned and described by a number of writers on the subject, but no satisfactory account of their development has yet been published. They appear quite early in the second period of growth, but are not readily seen until reagents are applied. When the section, however, is treated with chloriodide of zinc solution, or dilute Boehmer's or Kleinenberg's hæmatoxylin, they appear as circular uncolored places, and are large in proportion to the size of the cells on the walls of which they occur. They are to be found for the most part on the walls of the cells of the inner cortex and medulla, but are present sparingly on the walls of the innermost layers of cells of the outer cortex. In the inner cortex of older specimens the cell walls are very much thickened. There is an appearance like the middle lamella of wood cells, and the walls themselves are plainly stratified. The pit appears to be situated in the stratified portion, and to consist of two opposite depressions in the adjacent walls of neighboring cells, which are separated at this point only by a very thin membrane. When treated with chloriodide of zinc or iodine followed by sulphuric acid, the inner linings of the cells turn rapidly blue, and after a time there is a faint blue coloration through the whole thickness between two cells. The whole thickness, too, stains deeply with hæmatoxylin.

c. Medulla. — The tubes (or long tubular cells) are a conspicuous feature in sections of the adult plant, both of blade and of stipe. As we have seen, they arise very early in the history of the plant. It is somewhat obscure as to just how the first tube arises. Probably a middle cell is cut off between the two layers, and has a chance to elongate before another one is formed; for, as we have seen, the tubes in the young plant were few and scattered. Later, however, new tubes are formed from the inner cells of the inner cortex, and come to lie with the old ones in the medulla. The walls of these tubular cells begin to thicken before those of the other cells, and are of considerable thickness even in the preceding period. These cells form a layer adjoining those of the inner cortex on either side in the blade, and in the stipe this layer appears in cross-section as an ellipse of occasionally as many as four to six cells in thickness. The very central mass, both of the medulla of the stipe and of the medulla of the blade, consists of densely interwoven hyphæ, which have made their way in from the surrounding cells, and have crowded the tubes out to the periphery.

In the very old stipes, and to a somewhat less degree in the blades, the tubes form an important factor in rendering them as tough and leathery as they are. When such fronds are macerated in potash, the limiting and cortical layers may be removed, and a firm mass of fibrous tissue left, which is in the form of a flat plate in the blade, while that from the stipe is a cylinder hollow or spongy in the middle. This layer is unbroken at the transition place, which shows that in the adult plants this region is no longer the seat of active growth.

It is easy to isolate individual fibres from macerated specimens to get a better idea of their shape and size. They have, without exception, a longitudinal course, very nearly vertical, and lie closely crowded with overlapping ends. They are for the most part simple, but some are slightly branched at one end.

In a macerated stipe 9.3 cm. long, the longest fibre (or thickened tubular cell) was 7.5 cm. long, and was terminated only at one end, the other being broken off short. A whole one obtained from the same stipe was 7.3 cm. long, and one of more average length was 6.2 cm. long. A very small one measured 3.2 cm. The fibres from the blade are much shorter, averaging from 3 to 4 cm. in length.

In Figure 25, *a*, *b*, *c*, are represented the tips of various fibres as seen in optical section. They are of various shapes, and frequently have spiny projections which are probably traces of the connecting hyphæ with which in their earlier stages they were united with adjacent cells. In June plants, they have a thickened and stratified wall and a wide lumen. The contents at this time also line the wall, and are dense and of a yellow color. But in the specimens figured, which are from an October plant, the lumen is almost obliterated. The walls are composed of very distinct layers. The treatment with potash and a prolonged soaking in water are responsible for some of this, but not for the greater portion. The walls when treated with chloriodide of zinc solution finally become a pale watery blue.

These fibres, both as regards shape and arrangement, remind one of the fibres in the bands of brown tissue so common in the stems and stipes of ferns which are called *sclerenchyma fibres.* There seems to be no reason why these structures should not be called by the same name.

Sclerenchyma fibres occur also in *Saccorhiza bulbosa*, as I have learned from the examination of specimens in Professor Farlow's herbarium, but they do not seem to be so regularly parallel as in *S. dermatodea*. They have never been studied by any one, so far as I know. Even the references to them are few. Janczewski * mentions "cellules très-longues à membrane épaissie simulant des fibres libériennes," in "*Haligenia*," referring of course to *Saccorhiza bulbosa*. Kjellman, as I have mentioned above, both describes and figures them for his *Phyllaria dermatodea*. He says that they are also present (i. e. "the long tubular cells") in *Phyllaria lorea*, "but their walls are always thin, not differing in thickness from the walls of the adjoining parenchymatous cells." †

d. Splitting. — The splitting of the frond, although fairly regular and uniform, yet seems to be of the nature of a wound. In some specimens this splitting does not occur at all, but the majority of plants split early. The blade widens, and, being exposed to the buffetings of the waves, naturally tends to split. On account of the structure of the fibrous masses of tissue, it splits readily in a longitudinal direction rather than transversely. If the splitting happens when the plant is still young and actively growing, the limiting and cortical layers continue to increase, while the medulla, having no growth of its own, is left behind. Consequently, there is soon a depression or channel formed on the wounded edge. Under favorable conditions the sloping sides of this channel continue to grow until they meet and fuse, and then sections show no trace of the wound. In old specimens, however, these outer layers are not growing, and so, when the split occurs in such a frond, the edges exposed simply thicken and harden, and a section always gives evidence of the wound. Almost all the stages between these two conditions are met with.

e. Fruit. — The last organs to be developed are the reproductive organs. This occurs at Nahant and Peak's Island in the autumn and winter. Specimens just beginning to develop sporangia were found at Nahant in the last part of September, and fruiting specimens are to be found from that time on until May.

The reproductive organs are borne on the surface of the blade in large patches known as "sori." They are of two kinds, zoosporangia and paraphyses. The September specimens show many details of the development. The cells of the limiting layer elongate perpendicularly to the surface of the frond until they are ten to twelve times as long as broad. These elongated cells are slightly swollen at the tips, and have granular brown contents and constitute the paraphyses. At maturity, each is cut off from the cell whence it arose by a tangential wall. The cuticula has been carried up and still covers the tips of the paraphyses. After they are fully formed, the zoosporangia begin to appear as small and broad swellings at the bases of the paraphyses. They generally arise from the basal cell of a paraphysis; at least, in all cases where the point of origin could be distinctly determined this was the case.

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* Mém. Soc. Nation. Sci. Nat. Cherbourg, Tom. XIX. p. 98 (p. 2 of reprint), 1875.

† Arct. Alg., pp. 224, 225.

In November specimens, the zoosporangia are well developed. The cuticula has disappeared from over the tops of the paraphyses, and the sori in consequence have taken on their characteristic velvety appearance. The paraphyses themselves have a slightly thickened tip. The zoosporangia are in the shape of obovoid sacs, about two thirds the length of the paraphyses. The contents are of a light yellow brown and are already divided up into spheres, the future zoospores. The tip of the zoosporangium is noticeably thickened.

Farlow[*] has called attention to the fact that the paraphyses are destitute of the hyaline appendage of the paraphyses of the species of *Laminaria*. Areschoug[†] has given measurements of both zoosporangia and paraphyses. Kjellman[‡] figures a zoosporangium and a paraphysis; but these drawings do not correspond exactly to the zoosporangia and paraphyses of my specimens. Barber[§] has figured and described the zoosporangia and paraphyses of *Saccorhiza bulbosa*, which seem to agree very well with those of our plant.

GENERAL SUMMARY.

I. The development of *Saccorhiza dermatodea* agrees in its general features with what is known of the development of other *Laminarieæ*.

II. The permanent holdfast is developed from a peculiar organ, the rhizogen, which produces two successive whorls of hapteres, the first organ of attachment or primitive disk being only a temporary structure.

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[*] N. E. Alg., p. 96.

[†] Obs. Phyc., Part. III. p. 12.

[‡] Spetsb. Thall., II., Taf. I. Fig. 8, 9, 1877.

[§] Annals of Botany, Vol. III. p. 58, Pl. VI. Fig. 22.

III. The cryptostomata are present on the one-layered portion of the blade as clusters of hairs upon the flat surface; in the more complex portions, they occupy saucer- or bowl-shaped depressions; and these finally are provided with a prominent projecting margin, as shown above.

IV. The medulla is largely made up of hyphæ developed in the same way as in the other *Laminarieæ*.

V. Peculiar sclerenchyma fibres are developed in the medulla both of the stipe and of the blade.

VI. The paraphyses are destitute of the conspicuous terminal appendage present in almost all the other *Laminarieæ*.

VII. There is present a series of stages in which the maximum of growth is attained, and this series of stages is more or less sharply marked off from the adult stages by a process very similar to that known as "the renewing of the blade" in other *Laminarieæ*.

VIII. The adult frond is destitute of cryptostomata.

Relation to Phyllaria lorea, Kjellm. — Kjellman has made a careful study of the old *Laminaria lorea*, Bory,* and has decided that it is a distinct species, but high Arctic in its distribution. He has given his reasons for considering it distinct from the *Laminaria dermatodea*, De la Pyl., in the "Arctic Algæ." Strömfelt † follows Kjellman in keeping it distinct. I have searched for the species most carefully among my collections from the New England coast, and have studied Kjellman's descriptions in order that I might be able to recognize the plant. The following comparison between my experience with New England *Saccorhizæ* and Kjellman's with Spitzbergen and Norwegian specimens may throw some light on the subject.

Beginning with the young plants, Kjellman says that there is a marked difference between the two species. Young plants of *S. dermatodea* have a distinct stipe, a dark brown color, are "only little translucent, and provided with very few short-haired cryptostomata." The other species (*Ph. lorea*) has only a "very short stipe, passing without definite limit into a narrow, sometimes almost filiform, linear, or more usually lanceolate lamina. Their lamina is thin, very light brown, almost yellowish brown, perfectly pellucid with numerous long-haired cryptostomata." ‡

The great majority of the young *Saccorhizæ* to be found along the

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* In J. Ag., Spec. Alg., Vol. I. p. 130, 1848.

† Algveg. Isl., pp. 42 and 76, 1886.

‡ Arct. Alg., p. 224.

New England coast answer perfectly to this description of *Phyllaria lorea*. Only a very few were found which would at all agree with the description of *Ph. dermatodea*, and these few always seemed to be the product of unfavorable circumstances which had dwarfed them. The shapes too of the young specimens figured in the "Arctic Algæ"* agree very well with numerous specimens collected at Nahant. Kjellman further says, that "older specimens of the two species are easily distinguished from each other by several good characteristics. In *Ph. lorea* the stipe collapses in drying, and becomes flat, thin, almost membranaceous, and brittle; even in very large specimens, it has the same color as the lamina, being pellucid like this. In older specimens of *Ph. dermatodea* the stipe is far more solidly built, dark brown, opaque, flat upwards, but almost terete downwards."† Of my New England specimens, very large ones, in fact many of the very largest, answer almost exactly to this description of *Phyllaria lorea*. When dried, both stipe and blade become very thin and membranaceous, and extremely brittle. The stipe is light yellow-brown still in many cases, and the cryptostomata are very numerous and long-haired. In such specimens, too, the tubular cells are thin-walled, and with a very wide lumen. It is not until very late that these plants have cryptostomata with a prominent overhanging margin. They have all the characters, so far as I can see, that distinguish *Ph. lorea* from *Ph. dermatodea*. But these same specimens, as observed in tide pools at Nahant, soon begin to lose these characteristics. They become thicker and more solid both in stipe and in blade; they grow darker; they become shorter; the distinction between stipe and blade becomes more marked; — in fact, they come to have all the marks which serve to distinguish the *Phyllaria dermatodea* of Kjellman. Furthermore, all the plants of *Phyllaria lorea* taken by Kjellman were young. Only one was taken which had zoosporangia in course of development.‡

Professor Kjellman has very kindly sent me specimens both of his *Phyllaria lorea* and his *Ph. dermatodea*. The specimens of *Ph. lorea* agree exactly with my young specimens, which undoubtedly belong to *Saccorhiza dermatodea*, while the specimens of *Ph. dermatodea* correspond in all characters except size to older specimens of the same. Most of my browner specimens are larger, but, as the species is very variable in size, this does not seem to me to be of any great importance. I have little hesitation in believing that the *Laminaria lorea*, Bory, and the *Phyllaria lorea*, Kjellm., are younger, and perhaps in certain cases more delicate, stages of *Saccorhiza dermatodea.*

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* Taf. XXIV. Figs. 1, 2.

† Arct. Alg., p. 224.

‡ *Loc. cit.*, p. 227.

In his recent paper on the Algæ of East Finmark (p. 74), Foslie describes some young stages of *Saccorhiza dermatodea* which seem to agree very closely with those occurring on the New England coast, and his remarks on these tend to confirm the views expressed above.

Forms of Saccorhiza dermatodea. — Kjellman * describes two forms of his *Phyllaria dermatodea,* one of which, f. *typica,* has abundant cryptostomata; and under this he makes a reference to Farlow's plant described in the New England Algæ. But, as I have shown, the adult plant has no cryptostomata, which character would tend to refer it to the other form, *arctica,* which has no cryptostomata in the adult condition. But f. *arctica* has few in the young condition, according to the description. Here, however, I may refer to what I have shown above, that Kjellman's description of the young *Ph. dermatodea* does not agree entirely with mine. As the Norwegian plant distributed by Areschoug agrees well with our New England specimens, it certainly seems to me that these two varieties or forms of Kjellman represent merely different stages in the life history of one plant.

In the paper on the Algæ of East Finmark alluded to above, Foslie describes two new forms of *Saccorhiza dermatodea* (p. 74). These, as nearly as can be judged from the description, exist also among New England specimens; but there is no constant difference, and they seem to me to be merely states of the same plant, differing in shape and color on account of difference in age, or with varying conditions of light, exposure, etc. F. *lanceolata,* as far as measurements and description indicate, is mostly a younger and more delicate form than f. *oblonga.* On the New England coast the matured fruiting plants are remarkably uniform in size, shape, and color for a species of the *Laminariaceæ,* and so I can see no reason for separating our plant at least into different varieties or forms.

Relation to Saccorhiza bulbosa, De la Pyl. — The resemblance between *S. bulbosa* and *S. dermatodea* is pointed out by De la Pylaie in his first paper.† The rhizogen and the production of the two whorls of hapteres are the same in both species. After that the rhizogen of *S. dermatodea* ceases to form hapteres, while that of *S. bulbosa* continues to do so indefinitely, and produces that characteristic organ, "the bulb." The development of the tissues in this organ is, so far as

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* Arct. Alg., p. 223.

† Ann. Sci. Nat., Ser. 1, Tom. IV. p. 179.

I can judge, essentially the same in the two species. *S. bulbosa*, too, is the only other alga, as far as is known, that possesses the peculiar sclerenchyma fibres. Furthermore, *S. bulbosa* has paraphyses of the same peculiar kind with *S. dermatodea*. Both are annual plants, while the majority of the *Laminarieæ* are perennials. These two species seem to constitute a distinct and natural genus, in which are also placed several smaller European species of more or less doubtful autonomy. *Saccorhiza*, proposed by De la Pylaie in 1829,* has the right of priority. *Haligenia*, proposed by Decaisne in 1842,† included *S. bulbosa* only. It was extended in 1856 by Le Jolis ‡ to include *S. dermatodea*. Le Jolis divided *Haligenia* into two sections: *Saccorhiza*, to include *S. bulbosa*, etc., and *Phyllaria*, to include *S. dermatodea* and others. *Phyllaria* has since been used by Gobi § and Kjellman ‖ as an independent genus. Kützing made *S. bulbosa* the type of the genus *Phycocastanum* in 1843.¶ There seems to be no need of separating the two species, and consequently they should both be included under the older name of *Saccorhiza*.

Relation to the other Laminarieæ. — The relation of these two species to the rest of the species of the *Laminarieæ* is at once complex and interesting. The first organ that suggests itself as important in this discussion is the holdfast. *Chorda* has in all probability the simplest holdfast of any member of the group. The holdfast in this genus appears to be merely the primitive disk expanded. Nothing like hapteres is produced. *Laminaria solidungula* seems to reproduce the holdfast of *Chorda*, but on a larger scale. Next comes *Saccorhiza dermatodea*, in which the primitive disk does not produce hapteres, and where only two successive whorls of hapteres are produced from the rhizogen. *Saccorhiza bulbosa* differs not only in producing a greater number of whorls of hapteres from the rhizogen, and the consequent enlargement of that organ, but also in producing hapteres from the primitive disk as well.**

In the rest of the *Laminarieæ* the holdfast is more complex. In most cases the hapteres are numerous and branched, and it seems a difficult task to bring them into homology with these simpler forms. But they may be separated into two classes: *first*, those with hapteres in fairly distinct whorls; and *second*, those in which no arrangement into whorls can be traced.

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* Fl. Terre Neuve, p. 23.

† Ann. Sci. Nat., Ser. 2, Tom. XVII. p. 330.

‡ Examen I., p. 591.

§ Alg-Fl. Weiss. Meeres, p. 75, 1878.

‖ Arct. Alg., p. 223.

¶ Phyc. Gen., p. 346.

** Cf. Barber, Annals of Botany, Vol. III. p. 46, Pl. V. Figs. 1, 2, 3, and 5.

Laminaria digitata, as limited by the Swedish algologists,* is a good example of the first of these. The primary disk here produces a few hapteres. The second set of hapteres is produced in a whorl, slightly above the region of the primitive disk. As all the hapteres of this whorl start out at about the same time, there is a bulging of the stipe in that region, giving it for a very limited period somewhat the appearance of a rhizogen; but it does not long continue, and at no time is there as definite a structure as the rhizogen of the *Saccorhizæ.* The hapteres push out very early, and a second whorl soon appears above the first, another above that, and so on. Although there is no real rhizogen present here, yet this whorled arrangement and the consequent bulging appear so very similar as to suggest that the two methods are very closely homologous.

Of the second class, the common *Alaria esculenta*, as now limited, is a good example. The primitive disk here produces hapteres, and the next hapteres above generally come out one by one, and apparently irregularly, although at times they seem to form a more or less regular whorl or two.

As far as the holdfast is concerned, then, *Chorda* is the simplest form. Between *Chorda* and *Saccorhiza bulbosa* we might expect to find a simple form with hapteres arising from the primitive disk, but we do not. The intermediate form is *Saccorhiza dermatodea*, with a simple primitive disk and a rhizogen of limited growth. In regard to the holdfast, too, *Saccorhiza dermatodea* seems directly related to *S. bulbosa*, on the one hand, and the digitate *Laminarieæ*, on the other.

In structure, *Chorda* is perhaps the simplest: it has no trumpet hyphæ, and few ordinary hyphæ. The diaphragms, however, show a complication not present in other genera. *Saccorhiza* is of more complicated structure than *Chorda.* It lacks the trumpet hyphæ so characteristic of the other *Laminarieæ*, but possesses the peculiar sclerenchyma fibres in their stead.

The paraphyses of *Saccorhiza* are more like those of *Chorda* than those of the other *Laminarieæ*, being simpler in their structure.

Saccorhiza dermatodea, then, seems to be of simpler form and structure than any of the rest of the group except *Chorda.* It is Arctic in distribution, and circumpolar. This simplicity of structure and extended distribution seem to indicate that it is a primitive form, and more nearly related to the primitive ancestor of the *Laminarieæ* than any other known form except *Chorda*. *Chorda*, however, needs to be studied more carefully in order to determine its relationships more clearly.

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* Cf. Foslie, Die Lam. Norwegens, p. 60.

LITERATURE.

Below are given as many of the references to *Saccorhiza dermatodea* as have come to the knowledge of the author: —

Laminaria dermatodea, De la Pyl., Ann. Sci. Nat., Ser. 1, Tom. IV. pp. 179, 180, Pl. IX. Fig. G, 1824.

Laminaria dermatodea, De la Pyl., Fl. Terre Neuve, pp. 48 to 52, 1829.

Laminaria Bærii, Post. & Rupr., Ill. Alg., p. ii, 1840 (nomen).*

Laminaria dermatodea, Rupr., Tange Och., pp. 352 and 409, 1847.†

Laminaria dermatodea, J. Ag., Spec. Alg., Vol. I. p. 131 (exclus. syn. *L. Bongardiana*), 1848.‡

Laminaria lorea, Bory, in J. Ag., Spec. Alg., Vol. I. p. 130, 1848.

Phyllitis dermatodea, Kütz., Spec. Alg., p. 567, 1849.

Laminaria dermatodea, Harvey, Ner. Am. Bor., pp. 91 and 92 (ex parte), 1852.§

Haligenia (*Phyllaria*) *dermatodea*, Le Jolis, Comptes Rendus, Tom. XL. p. 473, 1855.

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* Areschoug referred this name as a synonym under his *Laminaria lorea*, No. 213 of his "Algæ Scandinavicæ Exsiccatæ," by virtue of a specimen received from Ruprecht. He makes a further reference to it in the "Observationes Phycologicæ, Particula Tertia" (p. 12). Gobi places it under his *Phyllaria dermatodea* in "Die Algen Flora des Weissen Meeres" (p. 75), giving Rostafinski as his authority for doing so. Kjéllman refers to Gobi as his authority for quoting this name as a synonym under the *Phyllaria dermatodea* of his "Algæ of the Arctic Sea" (pp. 223 and 225).

† Le Jolis in Examen II. puts under *Haligenia* (*Phyllaria*) *dermatodea*, "nec Rupr.," referring probably to this reference.

‡ Agardh quotes the *Laminaria Bongardiana*, Post. & Rupr., as a synonym of *Laminaria dermatodea*, De la Pyl., in the "Species Algarum," and has thus given grounds for the assertion (cf. Le Jolis, Examen I., p. 583) that the *L. dermatodea* of the "Species" was not the true *L. dermatodea*, De la Pyl. Agardh, however, in "De Laminarieis" (p. 33) explains how it was that he came to quote *L. Bongardiana* as a synonym of *L. dermatodea*, but asserts that nevertheless his reference really includes the true *L. dermatodea*, De la Pyl.

§ Harvey does not quote *L. Bongardiana*, Post. & Rupr., as a synonym; but his description of the old plants (for he says that he had seen only young specimens) was evidently taken from Agardh, and refers to some form of the true digitate *Laminariæ*.

Haligenia (*Phyllaria*) *dermatodea*, Le Jolis, Examen II., p. 312, 1855.*

Haligenia (*Saccorhiza*) *Bærii*, Le Jolis, Examen II., p. 312, 1855.

Haligenia (*Phyllaria*) *dermatodea*, Le Jolis, Examen I., p. 591, 1856.

Laminaria Bærii, Nyl. & Sael., Herb. Mus. Fenn., p. 73, 1859.

Laminaria dermatodea, Kemp, Canad. Nat., Vol. V. p. 34, 1860.

Laminaria dermatodea, Harv., Proc. Linn. Soc., Vol. VI. pp. 158, 160, 166, and 167, 1862.†

Saccorhiza dermatodea, J. Ag., De Lam., pp. 31 to 33, 1867.

Laminaria dermatodea, J. Ag., Spetsb. Alg., p. 8, 1868.

Saccorhiza dermatodea, J. Ag., Spetsb. Alg. Till., p. 31, 1868.

Laminaria dermatodea, Lawson, Canad. Nat., Vol. V. p. 100, 1870.

Saccorhiza dermatodea, J. Ag., Grönl. Alg., p. 110, 1871 (*fide* Kjellman).

Laminaria dermatodea, J. Ag., Grönl. Lam. Och. Fuc., p. 11, 1872.

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Laminaria dermatodea, Jordan, Canad. Nat., Vol. VIII. p. 402, 1874.

Saccorhiza dermatodea, Aresch., Obs. Phyc., Part. III. pp. 11 and 12, 1875.

Laminaria dermatodea, Farlow, Proc. Am. Acad., Vol. II. p. 355, 1875.

Laminaria dermatodea, Farlow, Report U. S. Fish Comm. for 1875, p. 707, 1876.

Saccorhiza dermatodea, Kjellm., Spetsb. Thall., II., pp. 14, 15, Taf. I. Figs. 8 and 9, 1877.

Saccorhiza dermatodea, Kjellm., Alg. Murm., pp. 36 and 65, 1877.

Phyllaria dermatodea, Gobi, Alg. Fl. Weiss. Meeres, p. 75, 1878.

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Saccorhiza dermatodea, Collins, Torr. Bull., Vol. IX. p. 71, 1882.

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* Examen I. was presented to the Imperial Academy at Breslau in 1854, but was not published until 1856. Examen II. was published in the Memoirs of the Imperial Academy at Cherbourg in 1855. In the mean time a summary had appeared in the Comptes Rendus (Tom. XL. p. 470), and reviews in the Annals and Magazine of Natural History (2d Ser., Vol. XV. p. 318, April, 1855), and in the Regensburg Flora, as is mentioned in a note appended to Examen II.

† J. G. Agardh says, on page 18 of "De Laminarieis," that *L. dermatodea*, Harv., "in scedula," is his *Laminaria fissilis*, and adds, "sec. specim. distrib."

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Phyllaria lorea, Kjellm., N. Ishafv. Algfl., pp. 282 and 283, Taf. 24, Figs. 1-3, Taf. 25, Figs. 5, 6, 1883.

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Exsiccatæ.

Laminaria lorea, Aresch., Alg. Scand. Exss., No. 213.

Saccorhiza dermatodea, Farl., Eaton and Anders., Alg. Am. Bor. Exss., No. 120, 1879.

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CRYPTOGAMIC LABORATORY, HARVARD UNIVERSITY,
June 1, 1891.

EXPLANATION OF THE FIGURES.

PLATE I.

Fig. 1. Diagram of a very young plant rather narrower than the typical form. The midrib-like portion is shaded. × 10.

Fig. 2. Diagram of a very young plant of the typical form. The midrib-like portion is shaded as in Fig. 1. × 10.

Fig. 3. Sketch of a young plant from Nahant, showing no trace of a rhizogen. A = the primitive disk; C = the stipe; D = the more complex blade; E = the primitive blade. × 1.75.

Fig. 4. Sketch of a young plant showing the rhizogen at B. Other letters as in Fig. 3. × 1.

Fig. 5. Sketch of a young plant in which the hapteres are just appearing. × 1.

Fig. 6. Sketch of a plant somewhat more advanced. × 1.

Fig. 7. Sketch of the base of a young plant in which the hapteres (F) are well developed, but in which the primitive disk (A) still persists. × 1.

Fig. 8. Diagram showing the point of attachment of the primitive disk (1) and of each of the first set of hapteres (2). × 1.

Fig. 9. Sketch of the base of a young plant showing the primitive disk (A) still remaining, the first set of hapteres attached, and the second set of hapteres just appearing. × 1.

Fig. 10. Sketch of the base of a small adult plant collected at Nahant in February, 1890, showing the permanent holdfast, the flattened stipe, and the "oar-shaped" base of the blade. × 1.

Fig. 11. Tracing of the outline of the base of a young plant having the appearance of "renewing the blade." At A is the constriction between the young and the adult portions. × 1.

Fig. 12. Diagram of a portion of a transverse section of the blade of a specimen 1.2 cm. long, showing at A and A the beginnings of the more complex portion. × 500.

Fig. 13. About 30 μ below the section represented in Fig. 12. × 500.

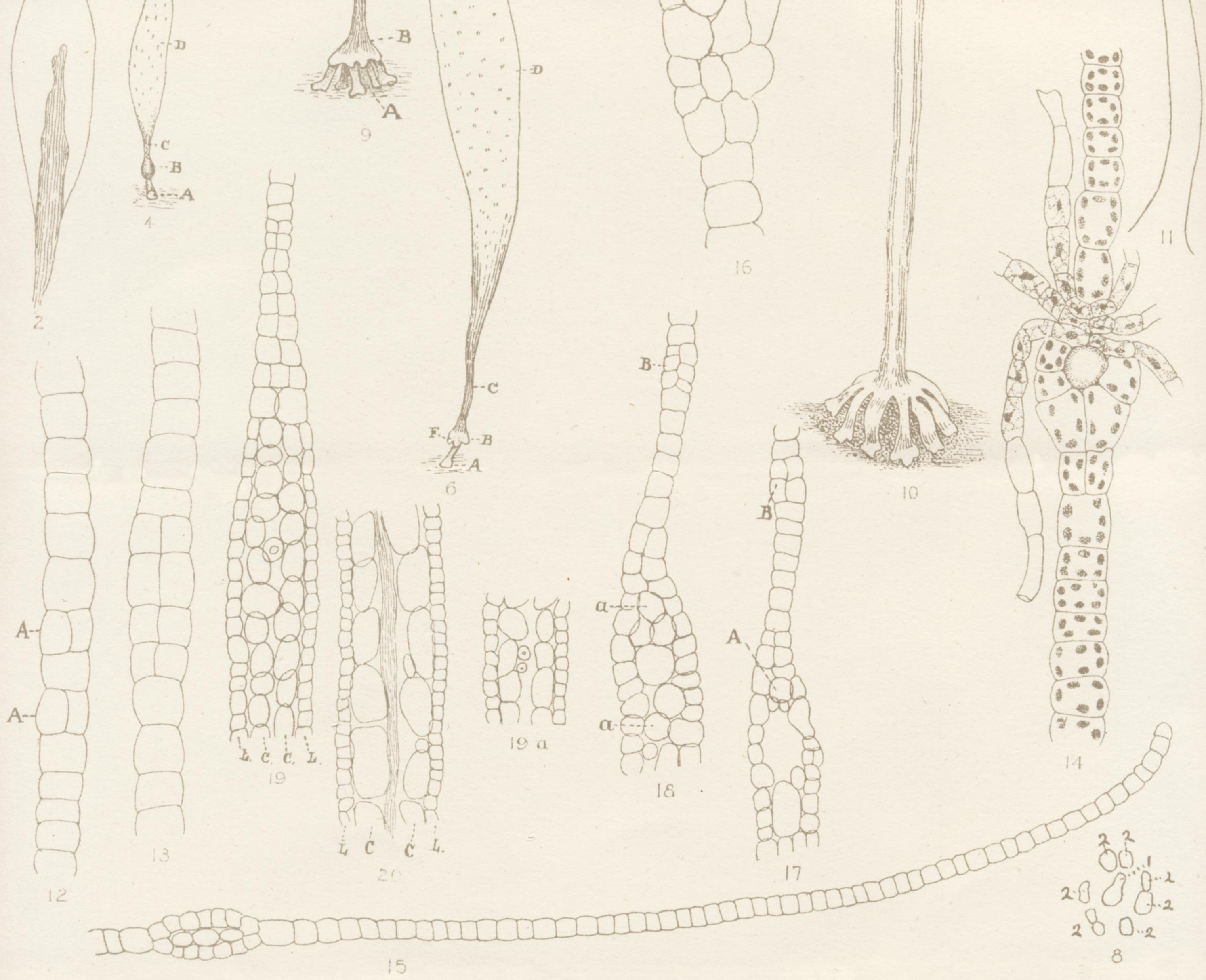
Fig. 14. Diagram of a portion of a transverse section still lower down on the same plant, showing the three-layered blade in the centre and the one-layered blade on the sides. In the very centre is shown the transverse section of a young sclerenchyma fibre, and at one side are the bunches of hairs belonging to young cryptostomata. × 500.

Fig. 15. Diagram of a little more than half of a transverse section below that represented in Fig. 14, showing the proportion existing between the three-layered blade of the centre and the one-layered blade at the sides. × 385.

Fig. 16. Diagram of a portion of a transverse section below that represented in Fig. 15. × 500.

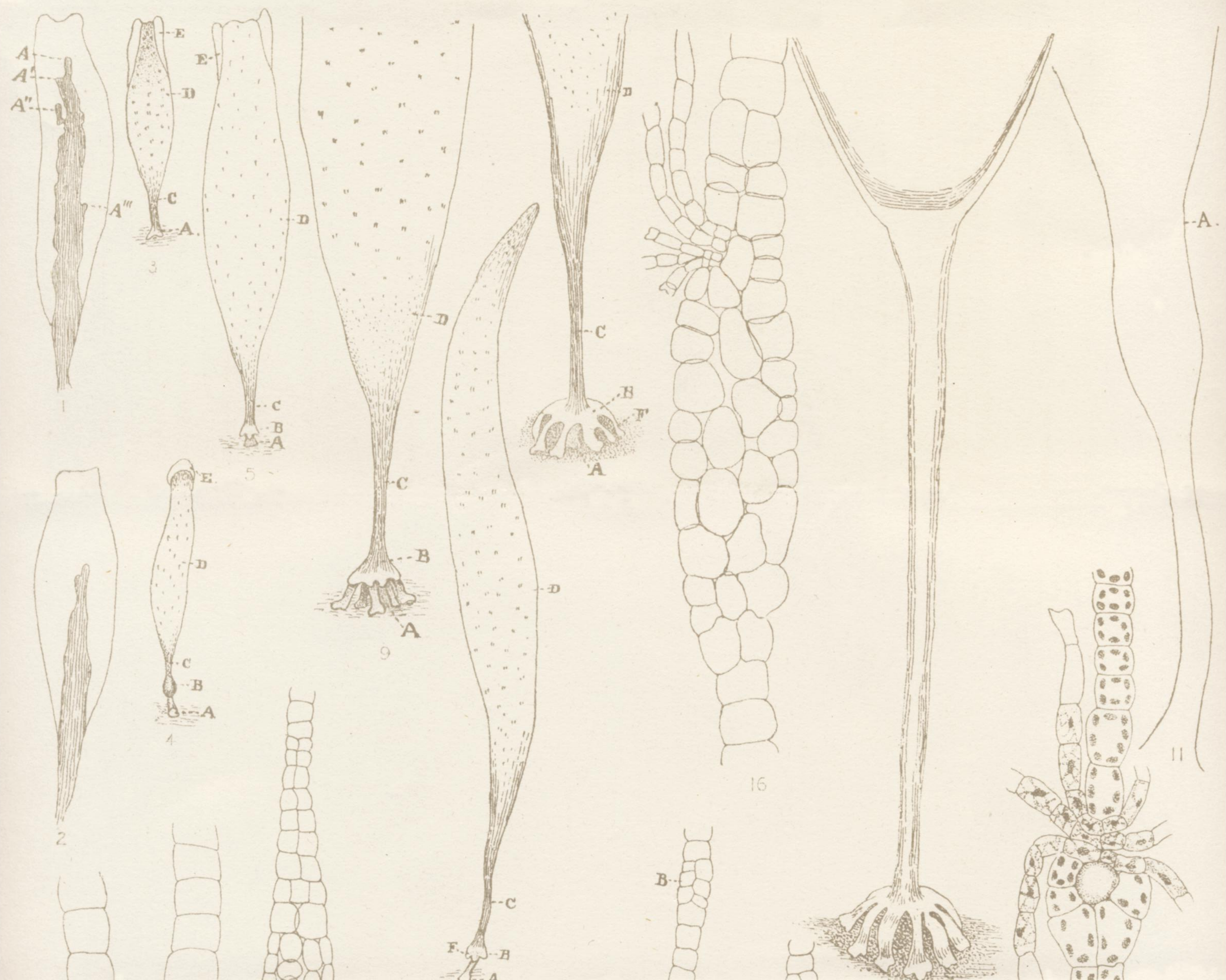
Fig. 17. Diagram of a portion of a transverse section showing at B the origin of a second more complex portion of the blade. At A is the transverse section of a sclerenchyma fibre. × 385.

Fig. 18. About 15 μ below Fig. 17. *a*, *a*, represent transverse sections of young sclerenchyma fibres. × 385.



Setchell del.

Heliotype Ptg. Co.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A'
A''
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1
2
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11

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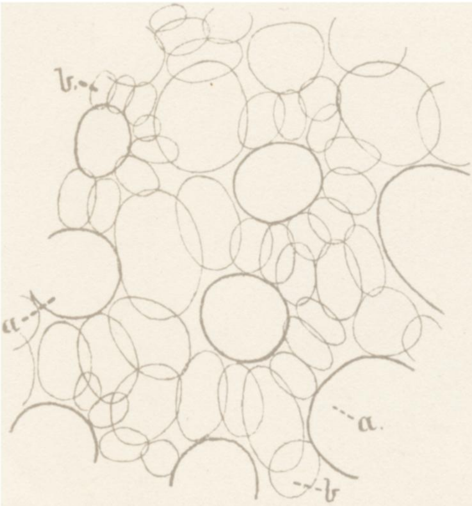
Plate II.



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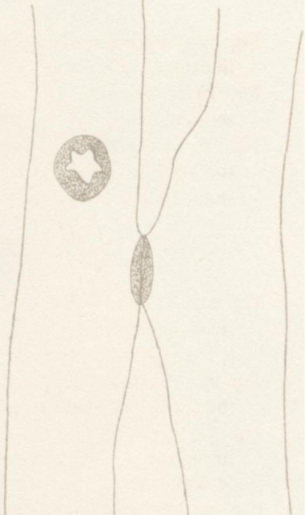

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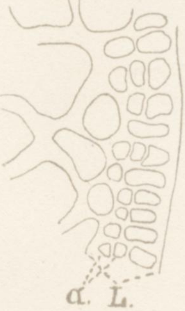

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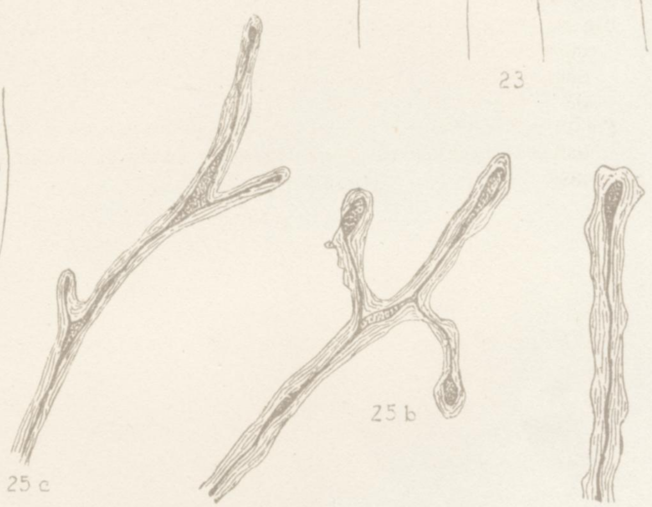
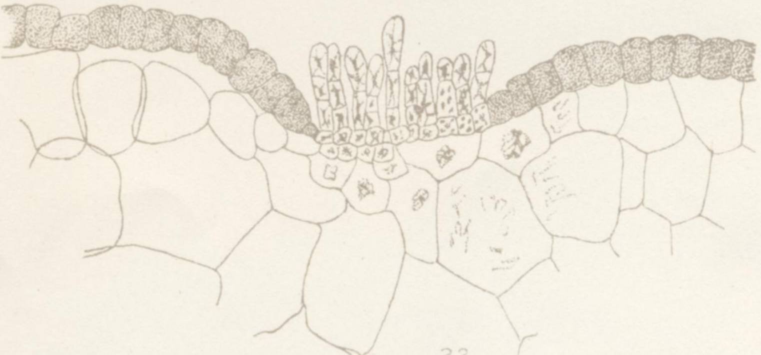

25 c

25 b

25 a



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Setchell, del.

Heliotype Ptg. Co.

Fig. 19. Diagram of a portion of a transverse section still lower down. L, L = limiting layers; C, C = cortical layers. × 385.

Fig. 19 *a*. Diagram of a small portion of a similar section showing two young sclerenchyma fibres. × 385.

Fig. 20. Diagram of a portion of a longitudinal section in the same portion of the blade as that represented in Fig. 19, with the same lettering. The shaded band in the middle represents a young sclerenchyma fibre. × 385.

PLATE II.

Fig. 21. Diagram of a portion of the centre of a transverse section through a rhizogen which has produced one set of hapteres. *a*, sclerenchyma cells; *b*, hyphal cells. × 500.

Fig. 22. Diagram of a section through the centre of a young cryptostoma in the transition place of a frond about 20 cm. long. × 500.

Fig. 23. Diagram representing portions of two elongated cells of the inner cortex of a young specimen, showing the thickenings around the pits. × 500.

Fig. 24. Diagram of a small portion of the margin of a transverse section of the stipe of a specimen collected at Nahant in September, 1889 L = the limiting layer; *a* = a couple of cells which have recently divided off from the peripheral cell. × 500.

Fig. 25, *a*, *b*, *c*. Diagrams of tips of sclerenchyma fibres seen in median longitudinal optical section From a specimen collected at Nahant in December, 1889. × 385.